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A REPORT ON THE WATER SUPPLY
FOR THE TOWN OF PORT STANLEY
WITH RECOMMENDATIONS FOR IMPROVEMENT
AND EXTENSION

by G. RAWLINGS
B.Eng. MICE.

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To the Crown Agents for the Colonies.

1.1. Gentlemen,

I have the honour to submit my report on the existing water supply of the town of Port Stanley, with recommendations for its improvement and extension.

My full terms of reference, which were communicated to me by you on behalf of the Falkland Islands Government in a letter M29523/D, dated the 21st of August, 1952, were:-

(a) To examine and report on the existing water supply of the town of Port Stanley and to make recommendations for its improvement, extension and conservation.

(b) To advise on improved methods of purifying the supply having regard, in particular, to the removal of peat stain.

My Commission to make the investigations and to report was given me by the Falkland Islands Government on the 15th of September 1952 and, before leaving for the Falkland Islands, I interviewed Mr. A.E. Livermore, Superintendent of Works, Falkland Islands, who was on leave in the United Kingdom, and Mr. G. Knowles of the Water Pollution Research Laboratory, Watford, who had recently made an examination of a sample of water taken from the supply.

1.2. I left London by air on the 10th of October 1952 and disembarked from the SS Fitzroy at Port Stanley on the 15th of October. Six months of exceptionally dry weather had preceded my arrival and the water supply was showing signs of its inadequacy. Thus, as excellent opportunity was afforded me to examine the deficiences of the two existing sources of supply and to assess the capacities of possible alternative sources under the driest conditions likely to arise.

1.3. A survey was first made of the existing supply comprising the Mount William intake, rough filters and pipe line, the Mullet Spring, pumps and pipe line and the town service reservoirs and tanks and the reticulations. This was followed by an investigation into the possibilities of improving or extending the existing sources or supply or of conserving their water by constructing a dam and impounding reservoir. As will be shown I found myself unable to recommend any scheme on these lines and turned my attention to finding a new, single, adequate source of supply where a treatment plant could be installed. When it was found to be unlikely that the rock underlying Port Stanley would be water bearing, the camp for a distance of some six miles around the Town was explored to find the best surface source and, for the reasons given in this report, the Moody Valley stream was selected.

1.4. At the request of the Honourable, the officer administering the Government in the absence of Sir Miles Clifford, an interim statement was made to the Executive Council of the Falkland Islands recommending that, subject to confirmation by a detailed survey, the existing sources of supply at Mount William and Mullet Springs should be abandoned and a new source of supply developed from the Moody Brook at a point about a quarter of a mile above where it flows into Stanley Harbour about two and a half miles west of Port Stanley. The very rough cost of the scheme was given as about £50,000, a figure which more detailed estimates made since, have found no cause to vary. The detailed survey of the scheme and the investigations into the flow of the Moody Brook and the quality of its water are described in the report together with the reasons confirming my recommendations to use this stream as the new source of supply.

1.5. A suggestion by the Agricultural Officer at the Executive Council Meeting that the Murrel River would be a better source of supply was followed up but, while the water from this river is of excellent quality and more than sufficient in quantity, the nearest point to Port Stanley from which it could be taken is three miles more distant than the proposed Moody Brook intake so that an extra pipe line of this length would be necessary if this source were chosen. However, by siting the new treatment plant at Moody Brook intake it will always be possible, at a later date, if the demand for water grows beyond what can at present be foreseen, to pump Murrel River water to the treatment plant and use the proposed Moody Brook pumping equipment to convey it to the Port Stanley service reservoirs. In other words, the Moody Brook scheme is capable of development by bringing in Murrel River water should the need ever arise.

1.6. A V-notch measuring gauge was installed on the weir at the trout-hatchery and the flow of the Moody Brook was observed from the 3rd of November onwards and co-related with the rain fall records of the Meteorological station at Port Stanley. When I left Port Stanley on the 21st of November 1952, the dry spell was still continuing and flow records were kept until it broke on the 29th November and for some days afterwards. A comparison of rain fall records, of which details are given in the report, shows that over the critical period drier conditions than the winter and spring of 1952 have only occurred perhaps four times in 48 years records and that the low flow in the Moody Brook measured on the 28th November 1952 on an average is not likely to occur more often than once in 12 years. The flow records, taken together with observations described in the report regarding the Moody Brook above the intake, show that the lowest flow measured is sufficient for the foreseen maximum requirements of Port Stanley.

1.7. A sample of water taken from the Moody Brook on the 20th of November was flown with me to the United Kingdom and examined by the Water Pollution Research Laboratory early in December. The Laboratory's report, attached as an appendix to my report, based on this single sample, states that the proposed source of water - the Moody Brook - will give a clear colourless supply after coagulation with aluminoferric (alum) provided that sodium carbonate (soda ash) is also added, and that, as it seems likely that the treated water will be corrosive, it will be desirable to add an alkali before distribution. The proposed treatment plant will include a coagulation stage using alum and soda ash and a stage where soda ash is added to the water to render it non-corrosive to pipes before it is pumped to the mains. It will also include filtration and sterilisation stages in accordance with accepted modern practice and be as described in this report and in accordance with the arrangements set out by the Paterson Engineering Company Limited in their letter to me of the 16th January 1953 and the accompanying drawing. The Paterson Engineering Company have very wide experience in the design and construction of water purification plants including the treatment of peat-stained moorland waters. On my return to the United Kingdom from Port Stanley I discussed this project with them and they agreed to submit a preliminary design and estimate for a treatment plant on the lines arrived at by us. The letter from the Paterson Engineering Company giving a description and approximate estimate of cost of the proposed plant forms an appendix to my report. Their co-operation in this respect has been most valuable.

1.8. The sample of water taken from the Moody Brook after a long spell of fine weather was less coloured and turbid than the water becomes after heavy rain. It is desirable therefore, and the water Pollution Research Laboratory recommend, that further samples should be taken at other seasons of the year for testing, particularly when the peat stain is most in evidence so that its behaviour and the chemical dosing required to treat it can be observed. Experience with peaty waters indicates that very deep colour can be removed successfully by the alum-soda ash coagulation process and there is no reason to doubt its efficiency with Moody Valley water under all conditions.

1.9. The succeeding sections of the report cover the topography, geology, climate weather and population of Port Stanley, a description of the existing water supply in detail and lead to recommendations regarding the existing water supply, proposals for a new source of supply with a scheme for purifying it and pumping it to Port Stanley, and recommendations as to how it can best be carried out together with approximate estimates of capital and operating costs.

2.1. PORT STANLEY AND THE SURROUNDING COUNTRYSIDE.

A topographical map, prepared by the Geographical section of the General Staff and published by the War Office in 1943 is the only map of this kind which has been made of the Falkland Islands. A photostat copy is attached to this report (Appendix Number 1). It covers Stanley Harbour, Port Stanley and the surrounding countryside to a distance beyond which it would be uneconomical to pipe water to the town. Port Stanley is the capital - and only - town of the Falkland Islands which lie in the South Atlantic Ocean between 54^{o} and 53^{o} south latitude and 57^{o} and 62^{o} west longitude and about 300 miles east, and somewhat to the North of, the Straits of Magellan. Port Stanley is situated on the north-eastern side of the easternmost of the two main islands - East Falkland - and lies along a narrow and sharply rising strip of land forming the southern shore of Stanley Harbour - an inlet from Port William, (which is itself an inlet on the north east coast) with which it is connected by a passage, the Narrows, upwards of 300 yards in width.

2.2. The town of Port Stanley extends for about $1\frac{1}{2}$ miles along the shore of the harbour and rises steeply inland for about half a mile to a height of some 150 feet above sea level. The main street - Ross Road - runs parallel with the shore and about 100 yards distant from it and here are located most of the important buildings - the Town Hall, the Secretariat, Government House, the Cathedral and the Falkland Island Companys jetty, stores and offices. Three other jetties - the Government, the Public and the west jetties - are also approached from it. Most of the houses, the two schools, the hospital and the few shops lie clustered on the hillside behind Ross Road in a rectangular layout of streets parallel to the harbour and running at right angles to it steeply up hill. The importance of this from the water-supply angle is the variation in level - and therefore in pressure head - between the lower parts of the town alongside the harbour and the higher parts of the Murray Heights. The maximum difference in level is about 130 feet.

2.3. The countryside surrounding Port Stanley is bare rolling moorland rising to rocky hills 500 to 800 feet high, forming small catchments none of which are more than a few square miles in area. The vegetation is sparse, there are no trees, and such shrubs as there are grow no higher than three feet. The top soil, which is extensively peat, lies thinly over the virgin rock to a depth of not more than a few feet. Rock outcrops and stone runs are frequent and distinctive features of the landscape. The grass is tough, coarse and white in colour and is intermixed with a type of heather (diddle-dee) mosses, Christmas bush and mountain berry. The natural drainage is through the top soil and along the underlying rock rather than over the surface of the ground. Typical moorland streams are found only in the lower valleys of the larger catchments and flow either eastwards and northwards into Stanley Harbour and the Murrel River or eastwards and southwards into Mullet Creek and Port Harriet.

3.1. GEOLOGY.

Geologically the Port Stanley area, including Mount William, the Moody Valley, Mount Longden, the Two Sisters and Mount Harriet, is formed in quartzite and quartzitic sandstones - intercolated with shales - of the carboniferous or Devonian series and much folded. The rock succession in the Falkland Islands has been investigated by H.A. Baker and published in his report on "Geological Investigations in the Falkland Islands 1920 - 1922". He found it to be essentially similar to that of the Cape Colony and he named the beds - downwards - as follows:-

Rhaetic (	West Lafonian Beds
Triassic (	Bay of Barbours Beds
Permian (	Choiseul Sound & Benton Rock Beds
and (	Lafonian Sandstones
Upper (	Black Rock Slates
Carboniferous (	Lafonian Tillite
(In lower part (of series)	Bluff Cove (Fitzroy Basin) Beds

UNCONFORMITY

Carboniferous or Devonian			Port Stanley Beds
Devonian			Port Philomel Beds
Lower Devonian	..	(	Fox Bay Beds
		(	Port Stephen Beds

UNCONFORMITY

Archaen	Cape Meredith series

Of the Port Stanley area, he says, it consists of gaunt barren ridges outcropping through a thin layer of clay and peat top-soil.

3.2. Stone runs - or rivers of stone - are an interesting natural phenomena in sub-antartic regions and are much in evidence around Port Stanley and other parts of the upper quartzitic series in East Falkland to which they are confined. A photograph of the Mount Will stone-run has been included in Appendix Number 2 and gives a good idea of their nature. They consist of loose blocks of stone two to six or more feet in size spreading to a width of some thirty to fifty feet and lying, perhaps, ten to fifteen feet deep, although there is no evidence of excavations having ever been made to verify the latter. Some run progressively downhill, others lie across the tops of low dome like hills, some are exposed, other are concealed by vegetation. The material in stone runs is always quartzitic and the blocks, which may be of considerable size - up to forty tons - but are more generally about two to four tons, are obviously derived by parting along the jointing and bedding planes of the virgin rock. J.R.F. Joyce in his "Stone-runs of the Falkland Islands" attributes their formation to the following :-

1. A rock series of jointed quartzites interbedded with easily weathered shales.
2. Small sharp folds in the strata in anticlines.
3. A tundraic climate of alternate freeze and thaw.

He considers that these factors cause denudation of the quartzite scarps which retreat, leaving their blocks as debris in their original positions, to form "stone-runs". When investigating proposals for a water supply, the importance of the stone run is in the complication it introduces into the construction of dams and reservoirs. Excavation for the dam foundations, which must be carried down to the virgin rock, becomes difficult and laborious so that it is not easy to estimate before work commences the extent to which excavation will be necessary in order to reach a watertight strata. Stone-runs within the reservoir area form courses for underground drainage which must be located and sealed before the reservoir is watertight. Many stone-runs are covered by peat and topsoil and cannot be found by surface examination. The hazards of building a watertight dam and impounding reservoir in the Port Stanley area are therefore considerable and success might only be achieved after excessively expensive work.

4.1. <u>CLIMATE AND WEATHER</u>.

Port Stanley is about as far south of the equator as London is north but, due to the influence of ocean currents, the temperatures at all times of the year are lower. The mean annual temperature is 42°F, with January (mean 48°F), the warmest month, and July (mean 35°F) the coolest month, thus giving a mean annual range of 13°F. The corresponding mean temperatures at Kew Observatory (London) are Annual 50°F, July 63°F, January 39°F, so that in Port Stanley the winters are slightly colder and the summers much cooler than in London. The absolute maximum temperature recorded in Port Stanley is 75°F and the absolute minimum 13°F. The annual mean maximum is 48°F and the annual mean minimum is 36°F. The mean annual diurnal range of temperature is small (5.9°F), varying from a monthly mean diurnal range of 8.3°F in November to only 2.9°F in May.

4.2. The relative humidity of Port Stanley is always high, the annual percentages being:- mean maximum 98, mean minimum 59, mean 81%. Humidity is greatest in the winter (July mean maximum 99, mean minimum 70 mean 88%) and lowest in the summer (December mean maximum 98, mean minimum 55, mean 74). The absolute maximum relative humidity recorded is, of course, 100% and the absolute minimum 29%. The diurnal range of humidity is greatest in the summer (February monthly mean 21.6%) and least in the winter (June monthly mean 3.6%). The sky conditions in the average month are two days clear, fourteen days part cloudy and fourteen days cloudy with small variation throughout the year. The annual mean sky conditions, based on three years observations, are 7.3 tenths cloud. Frequent high winds are a characteristic of the climate. For 1948, records show, calms 0.7%, 1-3 mph winds 3.9%, 4-15 mph winds 38.9%, 16-31 mph winds 47.7% and over 32 mph winds for 8.8% of the time.

4.3. The intensity and distribution of rainfall is the most important climatic factor influencing the quantity of water available as run-off at a source of supply and it is fortunate that fairly full records have been kept at Port Stanley since 1874. There have been breaks in their continuity between 1879-80, 1891-1905, 1914-15, 1920-29 and in 1950 but data is available for about 48 years between 1874 and 1952, sufficient to compare the dryness of 1952 with other dry spells and estimate their frequency. The records of all monthly rainfalls available since 1874 are set out in Appendix Number 3. From these it will be seen that the rainfall at Port Stanley (mean annual 27.50 inches) is well distributed throughout the year. The wettest months are December and January (means 3.00 and 2.87 inches) and the driest, September and October (means 1.63 and 1.55 inches). In the driest month ever recorded, September 1905, 0.35 inches fell and in the wettest, January 1911, 6.64 inches. The driest year, 1877, totalled 18.77 inches and the wettest, 1911, showed 36.96 inches. The average annual rain fall at Kew Observatory is 23.80 inches with monthly means varying from 2.70 to 1.45 inches so that the rainfall at Port Stanley is not greatly different from that at London, being slightly heavier, with more rainy days. The average number of rainy days (0.01 inch or more) at Port Stanley is 223 per annum varying from 14 in October to 22 in January. The corresponding figure at Kew is only 167 per annum. Heavy rainfalls (ie greater than 1.0 inch in 24 hours) are infrequent and average only 17 per annum.

4.4. In order to obtain comparable statistics, the following definitions were introduced in "British Rainfall 1887".

Absolute drought, a period of at least 15 consecutive days none of which is credited 0.01 inch of rain or more.

Partial drought, a period of at least 29 consecutive days the mean daily rainfall of which does not exceed 0.01 inch, ie a total of 0.29 inches.

By these standards, it is doubtfull whether a drought partial or absolute is ever experienced in Port Stanley when one considers that rain falls on an average 223 days out of 365 and 0.35 inches is the least rain recorded to have fallen in 30 days. When corelating rain fall with stream flows, it is dry spells of long duration, when rain-falls run much below the average, that are more important and have greater effect on run-off, than shorter periods without any rainfall at all. The late G.J. Symonds, in dealing with the record dry year 1887, put forward a definition of an engineer's drought which serves as a useful criterion. He defines it as

"A period of three or more consecutive months, the aggregate rainfall of which is less than half the average for that period." Although dryness of this intensity is not experienced in the Falkland Islands, it is by judging rainfalls of such periods (three or more months) that corelation with stream flows can best be made and critical flows assessed. The following data has, therefore, been abstracted from the monthly rainfall records of Port Stanley (Appendix Number 3) and arranged to show the relative dryness of all observed dry spells since 1874.

Year	Dry Spell ended on	Inches of rain falling during the preceding months						
		1.	2.	3.	4.	5.	6.	7.
1952	29th Nov.	0.99	2.09	3.53	5.01	7.00	8.18	9.55
1949	31st Oct.	0.43	1.86	3.88	4.76	8.38	9.81	11.71
1946	31st May.	0.64	3.01	4.75	7.33	9.68	13.22	14.09
1945	30th Nov.	0.87	1.78	4.86	7.61	9.61	13.26	15.96
1938	31st Oct.	0.71	1.66	4.27	6.88	9.79	13.32	17.27
1934	31st Oct.	0.96	1.85	3.60	6.29	8.39	10.37	11.23
1917	30th Nov.	0.93	2.13	4.63	5.85	7.94	11.19	11.58
1912	30th Sept	0.99	2.64	3.55	4.84	6.36	8.50	11.19
1883	31st Oct.	0.55	1.98	3.15	5.78	7.51	9.20	12.50
1877	30th Sept	1.03	1.92	3.49	5.27	7.25	9.79	10.99
1876	31st Dec.	0.99	1.90	3.18	4.76	6.46	9.22	10.32
1875	30th Sept	0.84	1.75	2.93	4.36	6.51	8.91	10.67
Av.Year	31st Oct.	1.55	3.18	5.19	7.36	9.48	12.05	14.59
½ average	(Symonds definition of drought)			2.59	3.65	4.74	6.03	7.30

First it will be noticed that no "engineers drought" by Symonds definition has ever occured in Port Stanley. Then taking the periods of three months or longer of Symonds definition, we see the dry spell which ended on the 29th of November 1952 has only been exceeded for three months, four times (1883, 1877, 1876, 1875); for four months, four times (1949, 1912, 1876, 1875); for five months, three times (1912, 1876, 1875). And that for periods of six and seven months, it has never been exceeded. It may fairly be assumed, then, that the exceptional dry spell, which ended on the 29th November 1952, was one which is only likely to be repeated once in 12 years on the average, and is only likely to be exceeded by a small percentage, say 20%.

5.1. POPULATION.

The last census of population was taken in the Falkland Islands in 1946, but vital statistics, published in the biennal reports of the colony, bring records up-to-date. The following figures have been compiled from these sources.

Year	Total Population - of - Falkland Islands	Population of Port Stanley
1891	1,789	
1901	2,043	
1911	2,272	
1921	2,094	
1931	2,392	1213
1949	2,239	1252
1949	2,267	
1950	2,231	
1951	2,280	(say)1270

POPULATION CHANGES 1932 - 1945

Year	Births	Deaths	Natural Increase	Immigration - or - Emmigration	Net total change.
1932	51	12	39	-26	+13
1933	52	27	25	-26	-1
1934	54	28	26	-16	+10
1935	50	19	31	-36	-5
1936	45	21	24	-57	-33
1937	37	20	17	-25	-8
1938	41	20	21	-34	-13
1939	47	17	30	+17	+47
1940	37	20	17	-37	-20
1941	58	30	28	0	+28
1942	41	34	7	+11	+18
1943	44	27	17	-26	-9
1944	54	30	24	-107	-83
1945	33	29	4	-79	-75
Totals	644	344	310	-441	-131
Averages	46	24	22	-31.5	

POPULATION CHANGES 1949 - 51

Year	Births	Deaths	Natural Increase	Immigration - or - Emmigration	Net total change
1949	40	33	7	-8	-1
1950	35	26	9	-45	-36
1951	45	27	18	+31	+49
Averages	40	28 $\frac{2}{3}$	11 $\frac{1}{3}$	-7 $\frac{1}{3}$	+12

The Falkland Island are thinly populated, 2280 persons inhabit 4,618 square miles (approximately 1 person to 2 square miles), but of these, rather more than half, say 1270, are concentrated in Port Stanley where the population density is quite high (approximately 2,100 persons per square mile). The town has 308 dwellings, giving a density of approximately four persons per dwelling - no crowding or housing shortage is evident. The total population of the Falkland Islands over the past 20 years, as can be seen from the tables, has diminished by approximately 5%, but the population of Port Stanley has increased slightly during the same period. The peak year for the Falkland Islands was 1931 and from then, until the outbreak of the Second World War, the population remained steady, the natural increase of births over deaths being offset by emmigration. Between 1939 and 1943 movements into and out of the Islands approximately balanced and the population rose by natural increase. But during 1944 and 1945 there was a heavy exodus which caused a net fall of about 6% in the population. Between 1946 and 1950, the pre-war conditions, with emmigration balancing natural increase, returned. In 1951 there was a sharp increase by immigration, probably accounted for by personnel for the building operations in Port Stanley and for the construction of the freezer at Ajax Bay. In assessing the future population of Port Stanley, in order to estimate the maximum demand likely to be made on the water supply, it will be advisable to allow for a slow but steady growth. The present population of 1270 may increase at the average natural rate of increase (10 per 1000 per annum), say 12 per year to a figure of approximately 1,500 in 20 years. There are no indications of any developments in Port Stanley which would cause this rate of growth to be exceeded, but it is so small that it would be very susceptible to changing economic or other conditions. However, the estimated ultimate population of the water supply area will be taken to be 1,500 persons but, as will be seen, the new scheme is being designed in a manner that will allow for any increased demands that might conceivably arise by running the pumps for more hours.

WATER CONSUMPTION.

The existing water supply is not metered, but it is estimated that the water consumption at present of Port Stanley reaches a maximum of 33,000 gallons a day (if a ship happens to take water on a Monday) and averages 29,000 gallons a day. This gives an average consumption of 23 gallons per head per day - a low figure due to three reasons

1. Some sixty of the 308 dwellings are not connected to the piped water supply and obtain water by trapping rain from the house roofs and storing it in tanks.

2. Only about 100 of the 308 dwellings are connected to the water borne sewage system, the others use bucket closets from which night soil is collected and dumped into the harbour.

3. The demand for water for trade purposes is small.

In assessing the ultimate demand for water, it must be assumed that eventually all dwellings will be connected to the water supply and sewerage systems and that the night soil collecting arrangements will be abandoned. Allowance must also be made for ~~for~~ some trade developments. It is, therefore, estimated that the average daily consumption of water may rise to 40 gallons per head, that is to a total of 60,000 gallons per day.

7.1. THE EXISTING WATER SUPPLY OF PORT STANLEY.

Port Stanley at present takes its piped water from two sources; the Mount William supply, installed in 1925-1926, and the Mullet-Springs supply, built in 1936. Their combined yield is inadequate in dry weather to meet the demand and the quality of the water delivered to the reticulation, especially from the Mount William source, leaves much to be desired. It is deeply coloured by peat stain at all seasons and, after heavy rain, its turbidity and colour are so great that, as it runs from the tap, it resembles tea rather than water and when standing a few inches deep in a bath completely obscures the bottom. The Mullet Springs water receives no treatment and the Mount William only an entirely ineffective passage through a "filter" - so called - which will be described later. The water is distributed unsterilised, corrosive to metals, and highly coloured. Its appearance is a long standing subject of complaint by the community, and housewives on many occasions find it impossible to us it for washing clothes because of the stains it causes. Lack of sterilisation would be most dangerous if pathogenic, water borne, bacteria were introduced into the supply, say by a typhoid carrier, and it may be that the intestinal troubles which occur so frequently are caused by less virulent bacteria in the water supply.

7.2. The Mount William supply is by gravity from a small spring issuing from the stone-run on the slopes of the mountain about three miles due west of the town, supplemented by two smaller springs situated near-by. All three springs are fed by surface water which, after percolating through the shallow peat topsoil, finds its way, either down the stone-run, or along small courses on the rock surface. The natural drainage of the slopes of Mount William is typically that of the "camp" area; that is percolating through the topsoil and sub-surface flow over the underlying quartzite rock along more or less defined channels, of which in this instance the stone-run is the largest, to a stream in the valley bottom - the Moody Brook - and hence to the sea - Stanley Harbour. The catchment of the northern slope of Mount William above the three springs is small, not more than two thirds of a square mile in area. There is no reason to suppose that all the drainage from the catchment is along the three courses that have been trapped, undoubtedly other drainage channels distributed across the slope carry water down the hill side to the valley bottom, all of them small and most of them drying out after a spell without rain. The stone-run forms the main collecting channel and advantage of this was evidently taken when, in 1925, it was adopted as the source for the first piped water supply for Port Stanley which, hitherto, had depended on rain water collected from roof-tops. A small headwall was constructed across the eastern part of the stone-run, thus intercepting the flow of water and diverting it into a 4" diameter cast-iron pipe. The inadequacy of this source must have been realised during the first dry spell for, in order to supplement it, the two nearest drainage courses lying about two hundred feet to the east were trapped and led through 2 " diameter galvanised pipes to the collecting point. In the original scheme, constructed during 1925-1926, a 4" diameter pipe carried water, without any treatment, direct to the service reservoirs, built at the same time, at Port Stanley.

7.3. The combined flow of the three springs at Mount William during normal rainy periods probably yields 100,000 gallons a day, more than the 4" diameter main can convey, but when little rain falls the flow diminishes rapidly. A measurement made on the 22nd of October, soon after my arrival in the Falkland Islands, registered 16,000 gallons a day flowing at Mount William; this fell away steadily during my stay until no more than 11,000 gallons a day were reaching the collecting point. Exceptionally dry weather persisted after my departure until the 28th of November 1952 and it will be reasonable to assume that the minimum flow at Mount William can drop below 10,000 gallons a day.

7.4. When Port Stanley came to rely on the piped water from

Mount William, and people abandoned their roof-water collecting tanks, the shortage of the supply in dry weather became apparent once more and, coupled with the unsatisfactory colour and appearance of the water, this led to investigations to find an alternative source of supply. A spring was found a foot or two below ground level, discharging through a pocket of sand, at the 175.00 level on the southern side of Sappers Hill at a distance of about 3,000 yds from Port Stanley. This spring is typical of the natural drainage of the camp area, in that it is fed by rain percolating through the top-soil and flowing over the surface of the underlying quartzite rock, but it differs because in this case the sand stratum acting as a natural filter removes some of the colour from the water. The proposal to develop this source wasaccepted, although it involved pumping the water to convey it to Port Stanley, and, in 1936, work on the Mullet spring supply was started. A concrete wall 10feet x 10feet was sunk over the spring from whence the flow is by gravity into a pump well, 8feet by 16feet by 5'3" deep (4,200 gallons capacity). Pumping plant was installed consisting of a Tangye, three cylinder piston pump, belt driven by a 7 h.p. [redacted] petrol engine, rated to deliver 3,000 gallons per hour. A 3" diameter steel pipe conveyed water to a covered Braithwaite pressed-steel tank of 100,000 gallons capacity which was erected on the Murray Heights behind Port Stanley at a top water level of 170.70 O.D. A photograph of this tank, which is still in very good condition, appears in Appendix Number 2.

7.5. The capacity of the Mullet spring proved to be insufficient to supply all the needs of Port Stanley so that the proposal to abandon the Mount William supply in its favour was not realised. Various expedients were employed to improve the supply. Two headings were opened up through the top-soil near the spring to collect surface water and the flows from them were led, by 2" diameter pipes, to a forebay discharging into the pump well; the arrangement of the forebay being such that either spring water or surface water from the headings - or both - can be fed to the pump well. An additional quantity of water was obtained from the headings, but at the expense of quality, as this water, like the Mount William water, does not benefit by flowing through a sand pocket and therefore is highly coloured after rain. It was found that the capacity of the pump was greater than the combined flow from the Mullet Springs and its contributory headers and a second expedient to improve the efficiency of the pumping system was adopted. A storage reservoir measuring 40 feet square and 2"6" deep (capacity 25,000 gallons) was built, sited about fifty feet away from the pump well and at such a level that the latter overflows into the reservoir when full and draws on it when emptying. In this way the capacity of the pump well (4,200 gallons) was increased by the capacity of the reservoir (25,000 gallons) thus giving ten hours pumping storage at the rated capacity of the pump (3,000 gallons per hour) so that continuous economical pumping shifts were possible. At a later date, when the troops left Port Stanley after the Second World War, a second Braithwaite steel tank became available from the camp water supply and a further expedient to improve the Mullet Springs supply was undertaken. The tank - an open one of 38,500 gallons capacity - was erected on the saddle of Sappers Hill at the highest point on the 3" diameter pumping main (about top water level 312.00 O.D.). This provided additional storage but, more important, improved the performance of the pump which was probably at this time not lifting more than one third of its rated capacity to the Murray Heights tank. The free water surface at the Sappers Hill tank shortened the length of pumping main by about 1200 yards and the water then flowed on by gravity to the Murray Heights tank. The full rated capacity of the pump, if it were ever achieved, was not maintained; a flow test made during my visit showed that the pump could not now deliver more than 1,800 gallons per hour.

7.6. The Mullet Springs supply, then, can deliver 1,800 gallons per hour to Port Stanley and when working a 56 hour week, (ie 7 days of 8 hours) can give about 15,000 gallons a day - or about half the present demand. During normal rainy weather the spring and the headers can yield more than this quantity, but during dry spells it falls away very considerably. In early November 1952, for instance, the yield was only 3,000 gallons per day from the spring and 7,000 gallons per day from the headers - a total of 10,000 gallons per day - sufficient to keep the pump running for 40 hours a week only. Even this is probably not the minimum flow and by the end of November it was probably less. The combined dry weather yields of Mount William and Mullet Springs supplies can be placed at a minimum of less than 20,000 gallons a day, probably as low as 18,000 gallons a day, against a present day demand of 30,000 gallons and an estimated future demand of 60,000 gallons. This then is the measure of the inadequacy of the existing water supply for Port Stanley.

7.7. The failure of Mullet Spring to give sufficient clear water for the town refocussed attention on the poor quality of the Mount William water and brought forth proposals for its improvement. Before anything eventuated, however, war had broken out in 1939 and eventually about 4,000 troops arrived in Port Stanley so that an urgent need for more, as well as better, water arose. The original Mount William system included two service reservoirs built at Dairy Paddock on the southwest boundary of Port Stanley (at elevation T.W.L. 135.00 O.D) fed by the flow from the stone-run spring at elevation 240.00 O.D. through a 4" diameter cast iron pipe. The reservoirs, which are still in good condition today, are uncovered, rectangular in plan, each 68'8" by 82'8" at the top with sloping sides, forming truncated pyramids 9'6" deep and retaining 7 feet of water, combined capacity 355,000 gallons. Two photographs of these reservoirs appear in appendix No: 2. They were constructed half in excavation and half in clay embankment and lined with precast concrete blocks set in cement mortar. They are in good condition except for some leaks through the top two feet of lining which needs repointing and one corner of the embankment which requires slight repairs.

7.8. In 1942, in an attempt to treat the Mount William water to remove peat stain, a break was made in the 4" diameter main at a point about a hundred yards distant, and 20 feet below, the stone-run intake and the combined flow of the stone-run spring and the two supplementary springs

springs was discharged. into a small pressed steel tank (see photograph appendix No: 2). Two filter beds - so called - were constructed to receive this flow with the object of improving the colour and delivering a water of better quality into the main. They failed for two reasons, first because filtration alone cannot remove colour and impurities of a peaty nature, and secondly because these filter beds were incorrectly designed. No provision was made for regulating the flow through them by controlling the head of water between inlet and outlet and they operated at too high a rate. Only 1,200 square feet of area was provided instead of about 4,000 square feet needed if the normal rate of 4 inches per hour were to obtain. The grading of the sand bed was too coarse for the zooglea and schmutzedecke organisms to build up, without which the biological process of filtration does not take place. The beds can only ever have operated as coarse strainers and never as slow sand filters. During my visit the beds were by-passed and out of service, and I gathered that they had been abandoned. Each bed is about 600 square feet in area and about 3'6" deep, constructed with mass concrete walls and rudimentary underdrains, and filled with coarse gravel and about 3" of coarse sand. As originally constructed they were trickling filters with pipe-sprinkler distributing systems which were removed because the sprinkler holes clogged. The water was then led on to the beds through holes in the side walls and, owing to the high rate at which the filters were operated, it is certain that the sand beds were never inundated or worked under a head of water. A photo of one filter inundated when receiving the pumped water from Moody Brook in November 1952, is included in appendix No: 2 but this unusual condition only occurs when the inflow exceeds the capacity of the Mount William main and causes a head to build up. It seems that the failure of the filter beds to improve the quality of the Mount William water was soon apparent and little care was taken to control their operation, which indeed, owing to fundemental faults in their design, was uncontrollable.

7.9. At the same time that this attempt was being made to improve the quality of the Mount William water, the need for a larger quantity of water to supply the troops had arisen and was met by improvised methods. A pump house was built at Moody Brook about 200 feet lower, and half a mile north, of the filter beds, and two small pumping sets and a 3" diameter steel pumping main were installed so that water could be pumped up from the Moody Brook to the filter bed and hence into the 4" diameter Mount William main at a rate of about 3,000 gallons per hour. The principal army camp was situated approximately half way between Mount William and the Dairy Paddock reservoirs, near and below the line of the 4" diameter main. Advantage was taken of this to give the camp a supply of water by gravity from the 4" diameter main by inserting a tee junction in it near the camp thus tapping part of the flow into a 38,500 gallon open Braithwaite, pressed steel, tank sited to command the camp. As we have seen this tank was afterwards dismantled and re-erected on the saddle of Sapper's Hill in the pipe line of the Mullet spring supply.

7.10. When the 4" diameter cast iron main from Mount William to the Dairy Paddocks reservoirs was new, in 1927, it must have been capable of discharging approximately 4,000 gallons per hour (96,000 gallons per day) and even in 1942, fifteen years later, after some incrustation had developed and the head been reduced 20 feet by the construction of the filters, there is evidence to show that it carried fifty or sixty thousand gallons a day to the camp and Port Stanley. Today, owing to the rapid and progressive growth of incrustations in the pipe, it is only capable of discharging about 32,000 gallons a day. This was proved by a flow test made on the 12th of November 1952, the details of which are set out in Appendix No: 4.

7.11. It has been established that, in periods of dry weather usually throughout October and November each year,- and in very dry years longer -, the combined capacities of the present sources of the Port Stanley water supply yield less than 20,000 gallons a day, while the demand is about 30,000 gallons a day, thus leaving a deficiency of approximately 10,000 gallons a day to be met. It has been seen that, during the war years, the supply was supplemented from Moody Brook and, although the pumps and engines used then are no longer in working order, the 3" diameter pipe up to

Mount William filter beds is still in existence and is employed each year to convey Moody Brook water to increase the Mount William supply. The motive power at present brought into service for this purpose is one of the Port Stanley Fire Brigade's trailer pumps and a photograph of the operation appears in appendix No: 2 while another photograph in the same appendix shows the discharge of Moody Brook water through the 3" pipe into one of the Mount William filter beds on its way into the main. The trailer-pump is a standard Merryweather's unit consisting of a petrol engine driving a 4" centrifugal pump capable of delivering 80 gallons of water per minute (approximately 5,000 gallons per hour) at a pressure of 115 lbs per square inch (equivalent to 265 feet of head). It can only develop the head necessary to lift water up to the filter beds (ie 200 feet static head plus about 65 feet of friction head) when delivering at least 65 gallons a minute. When in use, therefore, it discharges about 4,000 gallons per hour at the filter beds, but we have seen that the Mount William main to Port Stanley is now only capable of carrying 1350 gallons per hour (32,000 gallons per day). The capacity of the filter beds is about 15,000 gallons, so that, after the trailer-pump has been pumping for about 5 hours, the filter beds overflow and the pump must stop until their contents have been discharged down the Mount William - Port Stanley main at the rate of 1350 gallons per hour - say for about 16 hours, if allowance is made for an inflow of 400 gallons per hour (10,000 gallons per day) from the Mount William springs. Obviously then, the present method of supplementing the water supply in dry weather is an expensive and inefficient makeshift, and immobilises an important piece of fire fighting equipment for a number of weeks each year. The real cost of this improvisation is concealed because it appears that the Fire Brigade do not present the P.W.D. with a bill for the full cost of the loan of the trailer-pump. However, the fuel cost alone is seen to be a considerable item.

7.12. The water from the two sources of supply is delivered, as has been described, into service reservoirs at different levels. The Mount William water is held in the Dairy Paddock reservoirs (355,000 gallons capacity) at topwater level 135.00 O.D. and the

Mullet Springs water is stored in the Murray Heights tank (100,000 gallons capacity) at topwater level 170.70 O.D. The combined capacity, 455,000 gallons, represents 15 days supply at present consumption and 7½ days at estimated maximum future consumption. This is more than adequate by normal design standards and no recommendation to increase service reservoir storage capacity is necessary. The Dairy Paddock reservoirs are, however, uncovered and when a treatment plant is installed they should be covered to prevent deterioration of the water after treatment and before delivery to the consumer. A recommendation to this effect will therefore be made and an item for the cost included in the estimate. The configuration of the town is such that it has been necessary to keep the water reticulations served by the reservoirs and the tank separate from each other. The Dairy Paddock reservoirs supply the reticulation which feeds the part of the town lying below the 100 feet contour. The Murray Heights tank supplies the reticulation which feeds the higher parts of the town above this contour. The two reticulations are interconnected by a valve at the junction of Dean Street with Fitzroy Road which is normally kept closed so that they operate independently. The details of the reticulation are shown in the map at Appendix No: 5. There is an area of the town, around the Meteorological Station and along Callaghan Road, which is too high by some 25 feet to be served from the Murray Heights tank and no piped water supply is at present given here. Recommendations are made later in the report for supplying this part of the Town. Elsewhere, as the map Appendix No: 5 shows, about 80% of the houses and buildings are connected to the water reticulations. Service connections are by galvanised steel pipes screwed direct into the mains, no ferrules being used. The mains and service connections generally appear to be in fair condition but considerable incrustation has probably occurred due to the untreated water. There is no external evidence of leakages of any magnitude and, judged by the low demand per head of population, it is unlikely that much occurs. The mains meter on the Dairy Paddocks reticulation is not in working order and there is no mains meter on the Murray Heights reticulation so that it was not possible to check leakages by observing night flows. There are no service meters, water being charged for by assessment.

8.1. RECOMMENDATIONS REGARDING THE EXISTING WATER SUPPLY.

The description of the existing water supply to Port Stanley, in Section No: 7, underlines the inadequacy of the present sources of supply. The catchment of the Mount William source is barely $\frac{2}{3}$rds of a square mile in area, the catchment of the Mullet Springs is even smaller. The combined dry weather flow from them is less than 20,000 gallons a day. The only way in which the existing catchment could be developed to yield more water would be by conserving the surplus wet weather flows from them in impounding reservoirs and drawing upon these to supply the deficiency in dry periods. The wet-weather flow of the Mount William catchment would be just about sufficient, calculated on the following basis:- Rainfall of the driest year recorded = 18.77 inches assume 20% of the rainfall appears as run-off and the average daily yield in the driest year is then 100,000 gallons a day ($1\frac{2}{3}$ times the maximum estimated demand). In order, however, to balance dry weather flows with surplus wet weather water, to yield a constant 60,000 gallons a day, it would be necessary to provided an impounding reservoir capable of holding almost all the surplus run-off from the catchment during the wettest six months of the year and it is estimated that a capacity of at least six million gallons would be needed. The problem then becomes one of finding a site where the construction of a dam at an economic cost will create a watertight impounding reservoir of this size and it is here that difficulties arise. Examining primary considerations, the principle has been accepted that it will be neither economic nor desirable to construct and operate more than one treatment plant, therefore it follows that one source of supply must be developed to meet the total requirements of the town. The Mullet Springs supply is unsuitable for development because the estimated total run-off in a dry year is less than the estimated demand. When the Mount William catchment was explored and inspected it was found that this too was unsuitable for development because, although the estimated total run-off in a dry year is sufficient, the construction of a dam and impounding reservoir would be a hazardous and uneconomic proposition for the following reasons:-

(a) there is no natural dam site in the catchment and the configuration of the ground at the desired level is such that the dam would form the longest side of the reservoir;

(b) the ground slopes steeply and, therefore, the average depth of the reservoir would be small compared with the height of the dam;

(c) the rock formation is broken by a visible stone-run and, very probably, all the underlying rock in the catchment is fissured and jointed and there may be other concealed stone-runs. The task of carrying down the foundations of the dam to sound rock and of making the rock under both the dam and the reservoir watertight, would be formidable, hazardous and expensive;

(d) a great deal of labour would be required to construct the dam and impounding reservoir and shortage of labour is the principal embarrassment of the economy of the Falkland Islands;

(e) the existing main from Mount William to Dairy Paddock reservoir is no longer capable of carrying 60,000 gallons a day and would require replacing.

8.2. At an early stage in my investigations after exploring the Mount William and Mullet Springs catchments, I reached the conclusion that I would be unable to recommend any scheme for the improvement or extension of the existing sources of supply or for their development by conservation of their water in impounding reservoirs. I, therefore, make it my main recommendation that a new, single, adequate source of supply be selected and that the Mount William and Mullet Springs sources be abandoned.

8.3. Other recommendations concerning the existing supply are:-

1. That the Dairy Paddock reservoirs be repaired and covered by a roof of corrugated steel - or asbestos - sheets carried on steel trusses. The design and order for these should be placed through the Crown Agents for the Colonies.

2. That, when the new source of supply is operating, the Mount William - Dairy Paddock 4" diameter cast iron main be lifted cleaned by scraping, and used to improve the reticulation in Port Stanley, as and when defects show themselves, also the Mullet Springs 3" diameter main.

3. That, the mains-meter at the Dairy Paddock reservoir outlet be put into working order, any spare parts required being ordered through the Crown Agents.

4. That a new mains-meter be installed at the outlet to the Murray Heights tank, and that for this purpose a 4" diameter Torrent meter be ordered, through the Crown Agents, from Messrs. George Kent and Co. of Luton.

5. That the need for public standpipes - most of which are out of order - be reviewed and all the redundant ones removed.

6. That the part of the town lying above the level which can be fed by the Murray Heights tank should be served by a small pumped supply drawing water from the Murray Heights tank. In this scheme the capacity of the pump should be 10 gallons per minute and its motive power a fractional horsepower electric motor (say $\frac{1}{4}$ h.p.) fitted with an automatic stop and start mechanism. The pumping plant should be housed in a small building over a pumping well, sited adjacent to the Murray Heights tank and drawing water from it through a 4" diameter pipe with a ball-valve controlling the outlet. The pump should deliver water through a 4" diameter pipe to a covered pressed steel tank 12 feet x 8 feet x 4 feet deep (about 2,000 gallons capacity) raised on a steel staging to a topwater level of 195.00 O.D. The ground level at the Murray Heights tank is 158.50 O.D. so that, if the new high level tank were sited here, the staging would have to be 33 feet high - allowing a depth of 3'6" of water in the tank. The ground level near the Meteorological station is about 170.00 O.D. so that, if the new tank were sited there, the staging would have to be only 21'6" high. If the latter site is chosen, then the 4" diameter pumping main could be laid along Gallaghan Road and serve, in addition, as a reticulation main to the houses on the way to the tank and,

in this case, there would be no need for separate inlet and outlet mains to the new tank, the 4" diameter pumping-reticulation main serving both to fill and empty the tank as conditions demanded. The automatic stop-start control of the pump would be linked to the top water level indicator of the new tank and this apparatus can be supplied by Messrs. George Kent. Orders for this and the other equipment should be placed through the Crown Agents for the Colonies.

9.1. AN ALTERNATIVE SOURCE OF SUPPLY.

The selection of a new source of supply required an examination of several possibilities. The use of deep wells is always an attractive proposition in the absence of any obvious nearby surface source and merited investigation. A tentative attempt to find a ground-water supply appears to have been made in 1923 when two bores were drilled in the "camp", behind Port Stanley. One, at Spring Paddock, was sited where 5 feet of peat had previously been removed. It penetrated 22 feet of stiff clay, followed by 13 feet of boulder-clay and entered the quartzite rock at 35 feet below the surface. It was not taken any lower as the boring equipment was not capable of drilling hard rock. The second, on the east side of Sapper's Hill, after passing through a thin layer of surface clay, met a bed, 10 feet thick, of soft sandstone containing fossils; this was followed by peaty matter and, at 18 feet below the surface the hard quartzite rock was reached. These bores were said to have yielded between 200 and 400 gallons a day, but, as no pumping tests were made, it is not known whether even these small yields could have been sustained. The underlying rock was not bored into in either case and no examination of the water bearing possibilities of the quartzite strata was made. The water found was surface water which had percolated down through the overlying top-soil in the manner of the natural drainage of the camp area. The bores did little more than determine the thickness of top-soil over the rock at the selected points. An examination of the water bearing properties of the quartzite strata for the development of deep wells would be a much more extensive and costly business requiring diamond drills to penetrate the hard rock to depths up to 100 feet. Before recommendations could be made for such an investigation there should be geological indications that it would have a reasonable chance of success. These are absent. Quartzite, even when fissured and jointed, is not usually a water bearing rock, the topography and geology of the camp around Port Stanley is not hopeful, and there is nothing in H.A. Baker's report to indicate that his investigations led him to anticipate that the underlying rock in the Falkland Islands would be water bearing. I am therefore, led to recommend that no examination of the possibility of locating a ground water source of supply in the rocks underlying the top soil near Port Stanley be made, because the chance of finding a site for a deep well capable of yielding up to 60,000 gallons a day is slight and the risk of spending a considerable sum to no purpose is very considerable.

9.2. After the possibilities of developing the existing sources of supply and of finding a ground water source had been examined and dismissed, the investigation was narrowed to seeking the most economical surface source which would yield at least 60,000 gallons a day at all times of the year, because a reconnaisance of the camp for about 8 miles around Port Stanley had failed to reveal any likely dam-site which could be easily developed to form an impounding reservoir in which surface flow could be conserved. The chief streams within eight miles of Port Stanley are:-

(i) Mullet Creek Stream, which drains a catchment of about 4½ square miles to the south west of Port Stanley and enters Mullet Creek (which is an arm of Port Harriet) approximately 2¾ miles south west of the service reservoirs.

(ii) Moody Brook, which drains a catchment of about 6 square miles, due west of Port Stanley and enters Stanley Harbour approximately 2½ miles west of the service reservoirs.

(iii) The Murrel River, which drains a catchment of over 30 square miles, to the west and north west of Port Stanley and discharges into Port William through Fearnden water, north west of the town. The nearest point to Port Stanley from which fresh water can be taken from the Murrel River lies 5¼ miles distant from the service reservoirs.

9.3. The Murrel River, at the nearest point to Port Stanley has a dry weather flow many times greater than 60,000 gallons a day, Although accurate gaugings were not made when I inspected it in November 1952., I estimate that at least one million gallons a day were flowing. It is therefore, a much more than adequate source of supply, but, also, it is twice as distant from the town as the other two streams. Pipes are costly items and a 6" diameter cast-iron, cement lined, pipe laid in position with the necessary air, scour and sluice, valves is estimated at not much less than 18/-d. a foot. The extra capital cost of conveying water from this more distant source, therefore, would be more than £13,000, to which must be added the additional daily operating cost of pumping it 5¼ miles instead of 2½ miles. Obviously a nearer source is more economical if proved adequate.

9.4. Of the two nearer sources, the Moody Brook is preferred because

(i) Its catchment is six square miles against 4½ square miles for the Mullet Creek stream and its dry weather flow must be correspondingly greater.

(ii) It is slightly - ¼ mile - nearer to the Dairy Paddock Reservoirs and Murray Heights tank.

(iii) There is road access already existing which would have to be provided to reach the Mullet Creek stream.

(iv) The direct line from the Murrel River to the service reservoirs passes the point where water would be taken from the Moody Brook and where the treatment plant would be built. Therefore, if it ever became necessary to bring in Murrel River water, this could easily be done as an extension to the Moody Brook scheme.

9.5. Accordingly, the Moody Brook was selected for detailed investigation and survey of the stream and its catchment. The most important matter for investigation was to ascertain whether the dry weather flow is always in excess of 60,000 gallons daily. Here, some small difficulty arose in fixing a gauging weir through which the whole flow of the Brook could be directed. There is in existence a well-built concrete weir, sited about ¼ mile up the Moody Brook from the point where it discharges into Stanley Harbour, constructed in connection with a trout hatchery. The weir, a photograph of which appears in Appendix No: 2, is about seven feet high and 40 feet broad and creates a reservoir in the Brook about two hundred feet long which, it is estimated, contains 150,000 gallons. Unfortunately, the stream banks at the weir are low and a fairly substantial quantity of water finds its way down stream through the ground around both ends of the weir and from at least one point just up-stream. An attempt, therefore, was first made to construct a gauging weir about 50 yards below the trout-hatchery weir in the hope of trapping the whole flow of the brook. This proved unsuccessful owing to the broken rocky nature of the stream bed and banks and no greater proportion of the flow passed through the gauge than was passing over the trout-hatchery weir. It was abandoned and the decision was taken to place the gauge on the crest of the trout-hatchery weir and make an estimated allowance for the quantity of water which was by-passing this weir; this was done using pre-cast concrete blocks and a sheet-steel V notch, with the results shown in the photograph. Gauging readings were started on the 3rd of November 1952 and observed as frequently as possible until the 5th of December 1952 (the latest readings available). These readings - as has been seen in paragraphs 4.4. etc - covered a period when stream flows were as low as they are ever likely to be on a twelve year average and are as follows :-

DATE	GAUGE READINGS		Rainfall at Met.Station.
	Inches on V notch	Gallons per day	
3.11.53	5¾	210,000	Trace
4.11.53	5	150,000	0.08
5.11.53			NIL
6.11.53			0.12
7.11.53			Trace
8.11.53			Trace
9.11.53			Trace
10.11.53	5	150,000	NIL
11.11.53			NIL
12.11.53	4½	116,000	0.02
13.11.53	4¾	132,000	0.41
14.11.53	8	485,000	0.07
15.11.53	6½	290,000	0.02
16.11.53	5½	190,000	NIL
17.11.53	5	150,000	0.03
18.11.53	5	150,000	0.03
19.11.53	4⅞	142,000	NIL
20.11.53	4¼	101,000	NIL
21.11.53			NIL
22.11.53			NIL
23.11.53	3½	63,000	NIL
24.11.53	3½	63,000	Trace
25.11.53	3⅛	48,000	NIL
26.11.53	3	42,000	NIL
27.11.53	3	42,000	Trace
28.11.53	2¾	34,000	0.09
29.11.53			0.30
30.11.53			0.22
1.12.53	6½	290,000	0.04
2.12.53			Trace
3.12.53			0.02
4.12.53			Trace
5.12.53	3¾	74,000	0.05

Until the 13th of the month practically no rain had fallen in November after, as we have seen, a period of six exceptionally dry months; as a result the flow through the gauge fell away to 116,000 gallons a day. A not exceptionally heavy fall of rain on the 13th raised the flow through the gauge on the 14th to 485,000 gallons a day. A spell of fifteen days with practically no rain followed and the flow through the gauge fell away again to the disappointing figure of 34,000 gallons a day, just a little more than present daily requirements. However, a fall of 0.52 inches of rain on the 29th and 30th November again raised the flow so that 290,000 gallons a day were recorded by the gauge on the 1st December and, after a further five days without rain, this had fallen to 74,000 gallons a day by the 5th of December.

9.6. It is unfortunate that all the stream flow was not passing through the gauge and that an estimate has to be made of how much was escaping around the weir, in view of the fact that the minimum recorded flow for a period of four days was less than the estimated ultimate requirements of the town (although more than the present requirements). I hesitate to place the non-recorded flow around the weir higher than 15 gallons a minute (ie about 20,000 gallons a day) although this is a conservative estimate and it might well be more. We are, however, with the stream in its existing condition, evidently, at the trout-hatchery weir, below the margin of 60,000 gallons a day during exceptionally dry spells. So low a run-off from a catchment of 6 square miles in area is remarkable and required further investigation. The first area inspected in detail was that portion of the catchment which, lying to the south of Moody Brook, includes the northern slopes of Mount William and the stone-run. We have seen that there is from here, a minimum flow of about 10,000 gallons per day being taken into the Mount William - Dairy Paddock Reservoir main but, in addition, it was found that the flow from the foot of the stone-run was making its way down to Stanley Harbour in a channel which did not flow into Moody Brook. It was also found that only a small amount of work would be required to divert this flow into the reservoir in Moody Brook formed by the trout hatchery weir. This, together with the water at present going down the Mount William main to Port Stanley, would form a useful addition to the dry-weather flow. A more important state of affairs, influencing the run-off at the trout-hatchery weir of Moody Brook, was discovered by a detailed examination of the Brook above the weir right up to its source. The upper part of the catchment, below the Two Sisters and Goat Ridge, is drained in the manner which I have referred to as typical camp drainage - that is by percolation through the top soil and underground flow along the underlying rock surface. At a point about 2½ miles above the trout-hatchery weir, however, the underground flow is of such a magnitude and has collected sufficiently in the dips of the valley for regular water courses to have been formed. These courses, cut in the topsoil, join together about half a mile lower down becoming the Moody Brook which continues as a single stream bed down towards the trout-hatchery weir. So far there is nothing remarkable about the Brook which, as the photograph in Appendix No: 2 shows, is a normal moorland stream with well defined banks and a gravel and sand bed broken occasionally by ridges of the underlying rock where the latter has been only thinly covered by topsoil. But, at a point about 1½ miles above the trout-hatchery weir, the appearance of the stream bed changes; the ground becomes broken and boulder strewn, the well defined banks and bed cease and the stream disappears into an area of weathered rock and boulders, almost a stone-run. After, perhaps, a quarter of a mile, the stream reappears with regular banks and a less rocky bed, only to disappear again nearer the trout-hatchery weir in another rocky patch and not to reappear until only a few hundred yards from the weir. There are signs in the rocky patches that the Brook does not flow through them in a single definite course, but splits up into several channels and, it is probable, that not all of these reunite to form the stream on which the trout-hatchery weir is built. It is likely that there are other courses, running roughly parallel, which carry water under the top soil and through broken rock down to Stanley Harbour. It is very probable, then, that if the course of the Brook were canalised through the broken rock areas by clearing a regular bed with good banks, a substantially increased dry-weather flow would result. These two improvements are, therefore, recommended:-

(i) Bring the flow from the end of the Mount William stone-run, by a channel, to discharge into the reservoir formed by the trout-hatchery weir.

(ii) Construct a regular channel for the Moody Brook through the broken rock areas where none exists at present.

I consider that, if these works were carried out, the dry-weather flow of the Moody Brook at the trout-hatchery weir would be always sufficient to provide a minimum of Sixty thousand gallons per day for a water supply for Port Stanley, and I recommend that the Moody Brook be selected as the new source of supply and that the reservoir formed by the trout-hatchery weir be used as the intake.

10.1. RECOMMENDATIONS FOR PUMPING AND TREATMENT PLANT.

A very considerable part of the operating cost of a water purification and pumping scheme lies in the wages paid to the operating staff. If the scheme is designed to work 24 hours a day it is, of course, smaller, and therefore cheaper in capital cost, than one designed to cope with the demand in one shift; but this saving is more than offset by the need to employ and pay three sets of operating staff. It has been proved that for smaller schemes - say less than two million gallons a day - it is more economical to build them for operation on a one-shift-a-day basis. There is also the advantage that, in emergency, the plant can deal with three times its rated capacity daily by running the full 24 hours. This is useful if, for instance, an unusual demand - a big fire perhaps - has depleted the contents of the service reservoirs. It is proposed, therefore, that the pumps and treatment plant shall be capable of 100 gallons a minute (that is 6,000 gallons an hour). Present day demand then would be satisfied in five hours rising to ten hours when demand reaches the estimated maximum of 60,000 gallons a day. In emergency, with this plant, 144,000 gallons a day could be delivered and the Dairy Paddock reservoirs and Murray Heights tank (total capacity 455,000 gallons) filled from empty in a little over three days.

10.2. It is proposed that the site of the pumps and treatment plant shall be on the south side of the Moody Brook adjacent to the trout-hatchery weir, and that water shall be led in a channel from the reservoir formed by the weir to a suction-pump well situated at the side of the pump and treatment plant building. The ground here is subject to flooding in rainy weather, when the Moody Brook is in spate, and it is proposed that the floor of the building shall be raised 3'6" above ground level and the building approached by an embanked path from the road about 300 yards distant. The Paterson Engineering Company have prepared a sketch plan of the pumping and treatment plant building, which is attached as Appendix

No:7 of this report. The proposed building is 60 feet long by 25 feet wide with a wing 27 feet x 22 feet housing the sedimentation tank. Thus it is proposed that all the plant and machinery shallbe under cover, protected from the effects of frost, snow and rain. The cubic contents of the building are about 50,000 cubic feet so that, allowing a unit cost of 3/6d. per cubic foot, the estimated cost is about £9,000.

10.3. Some consideration has been given to the best method of driving the pumps. The water has first to be lifted to flow through the treatment plant - referred to as the low lift - and afterwards lifted to the service reservoirs - referred to as the high lift. The pumps are required in duplicate - making a total of four pumps - in order to provide stand-bys in case of breakdown. Electric light and power is required in the building. The most convenient arrangement would be for an electric supply to be given from the Port Stanley electric power house, but, on enquiry, it seems that the cost of running a line out to Moody Brook would be excessive because no other consumers are likely in that area. Individual diesel drive for two pumping sets, with high lift and low lift pumps on one shaft, was considered and estimated but, owing to the need to use non-standard equipment, it proved to be as expensive as electric drive. The arrangement selected is the most convenient and flexible one, and will provide for electric lighting, heating, and power in the building. It is proposed to install two diesel generator sets each of about 29 kilowatt capacity - one a stand by to the other - to produce electric power to drive four electric motors each coupled to a pump. The low lift pump motors would be 2 h.p. to raise 6,000 g.p.h. against a head of 33 feet and the high lift pump motors would be 15 h.p. to raise the same quantity of water against a head of 180 feet. The data for the pumps, showing how the heads have been computed, is to be found at Appendix No: 8. The arrangement of the pumps in the building and the circuit of the water from the suction sump, through the low lift pumps, the treatment plant, and the high lift pumps to the service reservoirs is shown in the Pattersons Engineering Company's drawing, (Appendix No: 7). It will be noticed that the treated water is collected in a balance tank of about one hours capacity (ie 6,000 gallons) placed under the floor of the building and that the suction pipes for the high lift pumps draw from this. Arrangements are included to balance the deliveries of the low and high lift pumps against each other as obviously these must be the same within narrow limits. It will also be noticed that the washwater for the filters is to be stored in a 6,000 gallon pressed steel tank placed on the flat roof of the building where it will provide the required head for back washing. The tank will be filled by a connection from the high lift delivery main (not shown in the drawing). The filter-wash waste water and the sludge water from the sedimentation tank will, on the occasions when back washing and desludging is in progress, flow from the point marked WASTE in the drawing, in an open channel direct to Stanley Harbour and not into Moody Brook below the weir. In this way any possible effect on trout from sludge or chemicals will be avoided.

10.4. It is proposed to convey the water from the high lift pumps in the building alongside Moody Brook to the Dairy Paddock Reservoirs and Murray Heights tank through a 6" inch diameter, spun-iron, cement lined, pipe laid along the line shown in the map, Appendix No: 1. A survey of the line has been made and it is the most direct one between the points of departure and arrival. It meets the road about 400 yards from the Moody Brook building, and follows it for another 400 yards until the road bends. It then strikes out straight for the corner of the race-course and follows the northern side of the course past the winning post and leaves the course at the north easterly corner. The pipe will then cross the paddock to the high ground behind Government House gardens and the football field and cross the Sappers Hill road near the bridge. From this point it will turn uphill to the south-west corner of the Dairy Paddock reservoirs and continue to the Murray Heights tank on the same line as the existing 2½" diameter main - which will no longer be required. A 6" diameter tee will be fitted into the main near the south-east corner of the Dairy Paddock reservoirs and a 6" diameter junction pipe will be laid from it to the existing twenty feet square concrete tank which adjoins the reservoirs at their division wall. It is proposed that this tank shall be remodelled to form a fore-bay to the reservoirs. The 6" diameter junction from the pumping main will be led into the fore-bay and will terminate in a balanced ball valve (Glenfield and Kennedy pattern H.45) of 6" diameter, working to a pressure of 25lbs square inch. The water level in the fore bay will be the same as the water level in the reservoirs and the ball valve will be adjusted to shut when the reservoirs are full and to open when the water level in them drops. A 6" diameter sluice valve (Glenfield and Kennedy pattern series No:2) will be fitted in the junction pipe so that flow to the reservoirs can be shut off even when they are not full to allow water to reach the Murray Heights tank. Arrangements will also be made for a by-pass pipe, 6" diameter, from the junction pipe to the reservoir outlet pipes near the mains meter in order that water can, when required, be pumped direct into the reticulation without passing through the reservoirs. The discharge of the pumping main into the Murray Heights tank will also be controlled by a 6" diamter balanced ball valve and a 6" diameter sluice valve and a by-pass pipe to the reticulation will also be provided. It is proposed that the pumping main shall be Class B (ie 200 feet working head) spun iron pipes to British standard specification No: 1211 of 1945, 6" nominal diameter, lined with ¼" thickness of cement, thus giving an internal diameter of 5.82 inches. Each pipe to be 12 feet long and jointed with a flexible mechanical joint of, for example, the Stanton screwed gland type, this will reduce the amount of skilled work in pipe-laying to a minimum and also the number of special bends required. The high lift centrifugal pumps should be protected on their delivery sides by non-return valves, preferably of the Glenfield and Kennedy "Recoil" type No: M.7. Air valves of the Glenfield and Kennedy double type with screw-down isolating valve (type H.40), 2" diameter should be fitted into the main at all summits on its line and at, at least, six places in all. Washout valves, 6" diameter, series No: 2 sluice valves, should be provided at all dips in the main and at, at least, four places in all.

They should be set on 6" x 6" Tees laid in the main. Provision should be made to isolate the main into four sections by introducing three series No:2, 6" diameter, sluice valves between the pumps and the Dairy Paddock reservoirs. A concussion relief valve of the Glenfield and Kennedy spring type (No: H20) should be set in the main near the pumps. The surveyed length of the pumping main is approximately 14,000 feet and the following calculations have been made of the probable friction head when the pumps are pumping 100 gallons a minute (6,000 gallons an hour). Velocity in main = 1.5 feet per second. Using the Hazen and Williams formula $V = 1.318C\ (D/4)^{0.63}(H/L)^{0.54}$ with C = 130 (for cement lined pipes) and D = 5.82 inches, the H/L (ie head lost per 1000 ft) = 1.7 feet, giving a total head lost in 14,000 feet of 23.8 feet, to which must be added an estimated allowance for head lost through valves and around bends, say 6.2 feet, making an estimated total friction head of 30 feet through the main when delivering at rated discharge of 6,000 gallons per hour. The main should be laid about 2'6" below ground level to be below the effects of frost.

10.5. A Sample of water was taken from the Moody Brook, at the trout-hatchery weir on the 20th of November 1952 in a glass winchester bottle and was flown home with me and examined by the Water Pollution Research Laboratory of the Department of Scientific and Industrial Research. A copy of their report is attached at Appendix No: 9, and their conclusions are reproduced below:-

"So far as can be judged from a single sample, the proposed source of water, the Moody Brook, will give a clear colourless supply after coagulation with aluminoferric (alum), provided that sodium carbonate (soda ash) is also added to keep the pH value within the optimum range.

As it seems likely that the treated water will be corrosive, it will be desirable to add an alkali to raise its pH value before distribution. Lime would be best, but we understand that it may be necessary to use sodium carbonate instead.

It is recommended that samples should be taken at all seasons of the year for tests of the nature described in this report, and the metal corrosive tests on treated water should be undertaken at the Falkland Islands. It would be difficult to make metal corrosion tests elsewhere since a supply of running water is required"

Taking the final paragraph first, arrangements should now be made to collect a sample of water from the Moody Brook after heavy rain, when the water will be carrying the maximum amount of peat stain and impurities, and send it by sea-mail in a winchester bottle, securely sealed and fully labelled, to the Water Pollution Research Laboratory, 103, Langley Road, Watford, Herts, addressed to Mr. G. Knowles, who has charge of the examination of Falkland Island water. There is little chance that the coagulation process, followed by filtration, will fail to remove all the peat stain and impurities; the examination of the heavily stained water is aimed rather at ascertaining what quantity of chemicals will be required to effect it. There seems to be no reason why the preliminary moves in the scheme should be held up pending the additional tests recommended. As regards metal corrosion tests, it is suggested that it be accepted that the treated water will be corrosive and steps taken in the treatment process to correct this by adding sodium carbonate to the water in the filtered water tank before it is pumped to the main. Sodium carbonate has been selected in preference to lime, for simplicity in operation and Mr. Knowles has confirmed its use.

10.6. Accordingly it is proposed that the treatment processes shall consist of

(i) Adding controlled doses of alum and soda ash

(ii) Mixing these so that coagulation takes place and aluminium hydroxide floc is formed

(iii) Removing the colloids, which form the peat stain, by allowing the floc to settle in a sedimentation tank

(iv) Filtering the sedimentation tank effluent through rapid gravity filters.

(v) Correcting the pH value of the filtrate to non-corrosive balance point by adding soda ash.

(vi) Sterilising the treated water before delivery into the mains by dosing with chlorine.

The Patterson Engineering Company of Windsor House, Kingsway, London, are specialists in the design and manufacture of water treatment plant of this type, and I have sought and obtained their co-operation in supplying a preliminary design and estimate of cost. This has been attached as Appendix No:6, and gives a full description of what we propose. The Patterson Engineering Company are preparing a more detailed drawing than No: 72846, together with a firm tender for the supply of the plant described, and will submit these upon request. In designing the plant the difficulties of constructing complicated re-inforced concrete structures at Port Stanley have been kept in mind and, apart from the flat roof of the building and the filtered water tank, re-inforced concrete work has been avoided by using pressed-steel work for the tanks and mild steel pre-fabricated filters. The design, throughout, has been with an eye to reducing the amount of work required at site. The Patterson Engineering Company, if the order is placed with them, will supply instructions and drawings for the erection of the plant and for its subsequent operation and will supply suitable laboratory equipment so that the tests necessary to ensure the correct chemical dosing etc. can be made daily. I recommend, however, that an experienced water-engineer be engaged for a period of about eighteen months to supervise the construction of the building, intake, and waste channels, the erection of the pumps, treatment plant, and pipeline, and the bringing into operation of the scheme as a whole. He will train staff to operate the treatment plant in the proper manner and make the routine control tests so that, upon his departure, the scheme will continue to function properly under the charge of the Superintendent of Works. I suggest that the Crown Agents for the Colonies be asked to engage the water engineer who should have had experience in the erection and operation of pumping-sets, sedimentation tanks, and rapid gravity filters in addition to the laying of water mains. Allowance has been made in the preliminary estimate for his salary and passages.

11.1. A PRELIMINARY ESTIMATE OF THE CAPITAL COST OF THE MOODY BROOK SCHEME.

Item	Description	£	s	d
		Estimated cost		
1.	The building (50,000 cubic feet) for pumps and treatment plant, including intake and waste channels ..	9000	0	0
2.	Canalisation of part of Moody Brook and channel for stone-run water	1000	0	0
3.	Pumping and purification plant in accordance with the Patterson Engineering Cos. approximate estimate F.O.B. British Port ..	15000	0	0
3a.	Shipping charges on 3 ..	1200	0	0
3b.	Erection charges on 3 ..	1800	0	0
4.	Pumping main from Moody Brook to the Murray Heights tank, supply, shipment, and laying, including valves meters specials, branches to reservoir etc. 14,000 feet at 18/- per ft. ..	12600	0	0
5.	Covering in Dairy Meadow reservoirs and the reconstruction of the forebay and repairs to reservoirs	3500	0	0
6.	Lifting, scraping, and storing of the Mount William 4" and Mullet Springs 3" mains against relaying in the reticulation ..	400	0	0
7.	Auxilary pumped supply and storage tank for Met. Station area	2300	0	0
8.	Expenses of supervising water engineer for 18 months ..	2000	0	0
9.	Contingencies 2½% say ..	1200	0	0
		£ 50,000	0	0

12.1. ESTIMATE OF TIME TO COMPLETE THE MOODY BROOK SCHEME.

The Paterson Engineering Company say that, based on present commitments and availability of materials, they estimate that shipment could be given of the purification and pumping plant in twelve months from the receipt of order. I estimate that, if the building is started about three months before the plant is shipped, it should be completed, with plant installed within twelve months of shipment date, ie operating two years after date of order. At the present time, pipes and valves delivery can be estimated as shipment twelve months after date of order. This will allow a further twelve months for shipment and laying. The same phasing can be estimated for the roofing for the Dairy Paddock reservoir, and the pump and materials for the auxiliary supply. The estimated time to complete the whole scheme is two years after the date orders are placed. The supervising water-engineer should be engaged to reach the Falkland Islands about eight months after the date orders are placed and he will then be able to discuss the details of the orders with the Crown Agents and the manufacturers before he leaves the U.K.

13.1. A ROUGH ESTIMATE OF THE OPERATING COST OF THE MOODY BROOK SCHEME PER ANNUM WHEN DELIVERING 30,000 GALLONS.PER DAY

		£	s	d
1.	Fuel for diesel generators operating 5 hours per day say 2,000 gallons per annum at 20d. per gallon	166	13	8
2.	Lubricating oil, spares etc. for generators say	33	6	4
3.	Spares and stores for pumps and treatment plant,	50	0	0
4.	Chemicals: Alum 3 tons per annum; Soda Ash 2 tons per annum; Common Salt one ton per annum	100	0	0
5.	Salary of Superintendent and cost of living bonus	350	0	0
6.	Wages of Labourer including C.O.L. bonus	200	0	0
7.	Electrical stores, cleaning materials etc.	15	0	0
8.	Contingencies 10% say	85	0	0
	Total	£ 1,000	0	0

It would be advisable to have a renewals fund for the pumps and treatment plant, based on a capital expenditure of £18,000 and a life of twenty years, say about £900. per annum.

14.1. SUMMARY OF RECOMMENDATIONS.

1. Abandon the Mount William and Mullet Springs sources.

2. Develop the Moody Brook as a new source by installing a pumping and treatment plant at the trout-hatchery weir, and conveying water to the existing service reservoirs.

3. Improve the dry weather flow of the Moody Brook by canalising the sections which at present run through broken rocky ground and also by leading in water from the end of the Mount William stone-run.

4. Cover Dairy Paddock reservoirs and carry out minor repairs to them.

5. Reclaim the Mount William and Mullet Springs mains for re-use in the reticulation.

6. Put the mains meter at Dairy Paddocks reservoirs in order.

7. Install a mains meter at Murray Heights tank.

8. Review the need for public-standpipes

9. Construct an auxiliary, pumped, reticulation for the high area around the Meteorological Station and along Callaghan Road.

10. Ask the Engineering Department of the Crown Agents for the Colonies to design the roof over the Dairy Paddock reservoirs and the auxiliary scheme for the Met. Station, - Callaghan Road area, and ask them to arrange for placing orders for the design and supply of the main scheme.

11. Engage a water-engineer, through the Crown Agents, to supervise the construction of the scheme and train operators.

12. Take a water sample from the Moody Brook after heavy rain and send it to the Water Pollution Research Laboratory for examination.

13. If, in subsequent years the dry weather flow of the Moody Brook proves insufficient for Port Stanley's needs, bring an auxiliary supply of water from the Murrel River to the treatment plant to supplement the Moody Brook supply. It is hoped that this recommendation will never need to be implemented.

G. Rowlings Pape

R/UTI/WAT/1#1-01

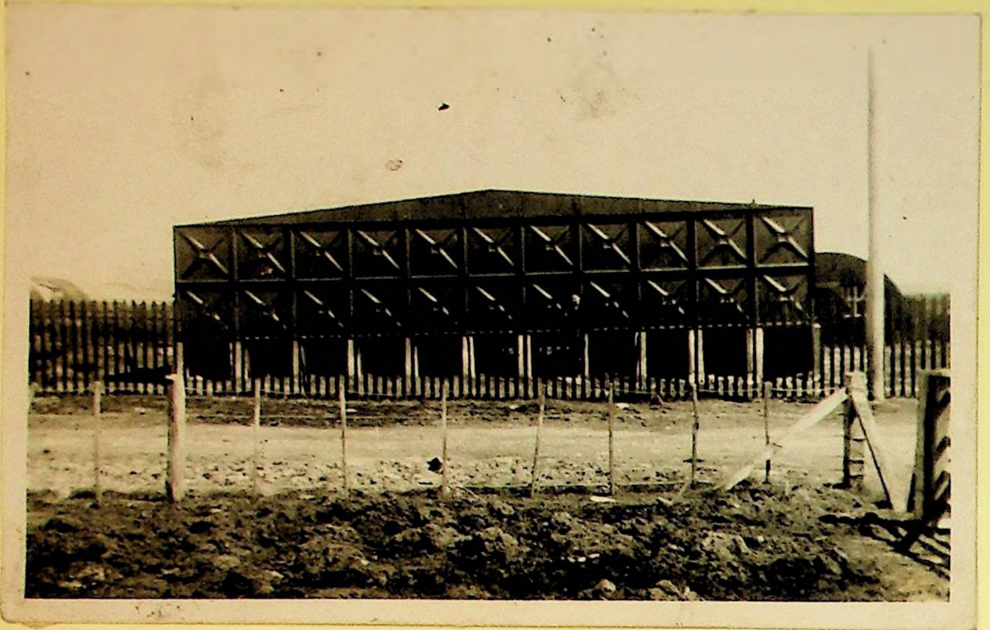
APPENDIX Nº 2

STONE RUN, MOUNT WILLIAM

R|UTI|WAT|1#1 - 02

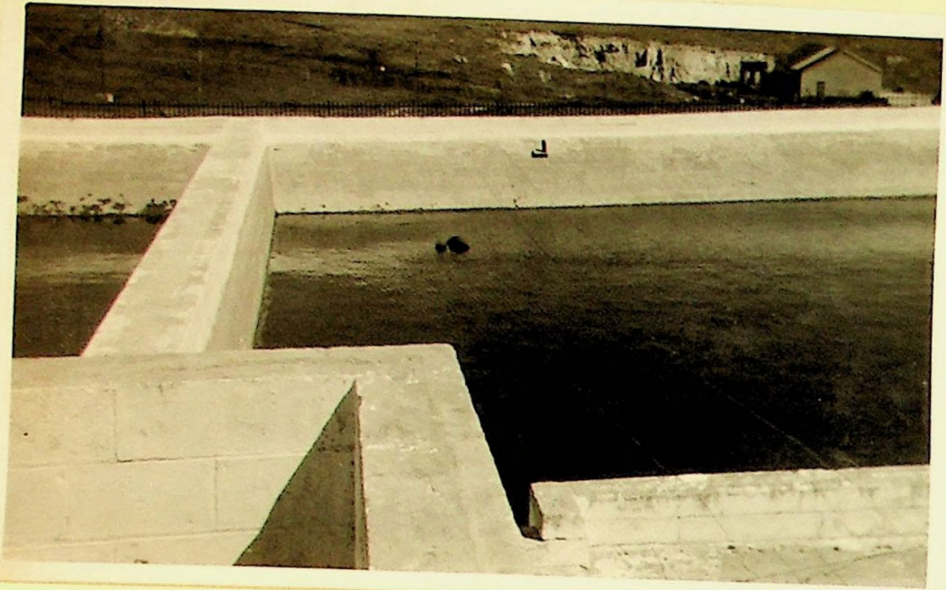
COLLECTING POINT, MOUNT WILLIAM

R UTI/WAT/1#1-03



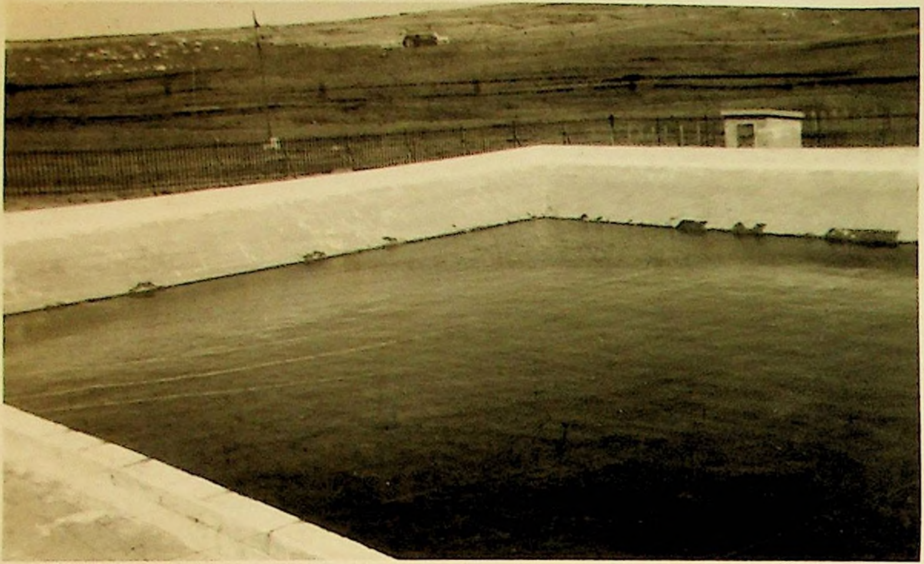
SERVICE TANK, MURRAY HEIGHTS

R/UTI/WAT/1#1-04



DAIRY PADDOCKS RESERVOIR, NORTH

R/UTI/WAT/1#1-05



DAIRY PADDOCKS RESERVOIR, SOUTH

R|UT1|WAT|1#1-06

FIRE PUMP AT MOODY BROOK, NOVEMBER 1952

R|UTI|WAT|1#1|-07

1952

MOODY BROOK AND THE TWIN SISTERS (NB: TWO SISTERS)

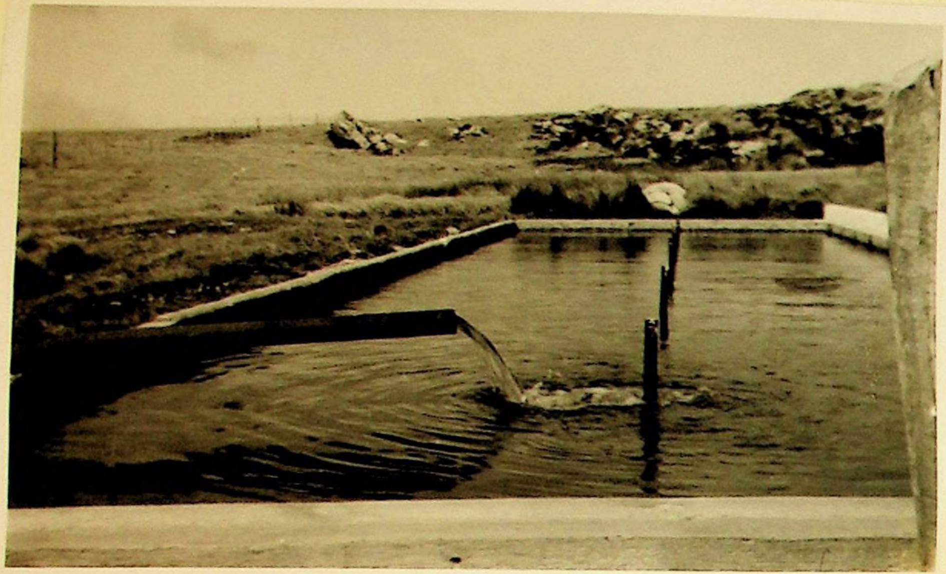
TROUT - HATCHERY WEIR AND POOL, MOODY BROOK. X = site for proposed treatment plant

R/UTI/WAT/1#1-09

MOODY BROOK NOVEMBER 1952

RIUTI WAT/II #1-10

1952



FLOW FROM FIRE-PUMP DISCHARGING AT MT WILLIAM FILTERS

R UTI WAT ||#| - || 1952

"V" NOTCH GAUGE ON TROUT-HATCHERY WEIR, MOODY BROOK

R|UTI|WAT|1#1-12

"FILTERS" MOUNT WILLIAM SUPPLY

APPENDIX NUMBER 3.

MONTHLY TOTALS OF RAINFALL AT PORT STANLEY IN INCHES.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total for year
1874	2.17	1.40	2.43	2.13	0.73	1.01	1.42	2.77	1.56	1.21	1.03	2.46	20.32
1875	3.27	3.32	1.76	2.40	1.45	1.43	1.18	0.91	0.84	1.07	1.24	2.92	21.79
1876	3.27	2.00	2.12	1.07	1.64	1.10	2.76	1.70	1.58	1.28	0.91	0.99	20.42
1877	1.60	1.23	1.20	2.54	1.98	1.78	1.57	0.90	1.02	1.71	1.27	1.97	18.77
1878	1.15	1.21	1.78	-	-	-	-	-	-	-	-	-	-
1879	-	-	-	-	-	-	-	-	-	-	-	-	-
1880	-	1.96	4.46	3.09	2.09	1.87	1.48	2.66	1.84	1.07	2.50	4.00	-
1881	4.00	2.10	2.52	2.99	2.37	2.91	3.09	2.01	1.87	1.95	1.77	3.45	31.03
1882	2.79	2.38	2.76	3.03	5.19	2.24	0.84	2.00	1.70	2.15	2.75	2.58	30.41
1883	3.31	2.99	5.34	3.30	1.69	1.73	2.63	1.17	1.43	0.55	2.07	3.18	29.39
1891	2.06	3.38	1.65	0.88	1.8[illegible]	-	-	-	-	-	-	-	-
1904	-	-	-	-	-	-	-	2.04	2.44	2.81	1.61	2.82	-
1905	3.57	4.57	1.90	2.11	2.81	2.55	2.58	2.09	0.35	1.29	1.07	2.77	27.64
1906	2.09	1.87	2.67	2.15	2.21	2.90	2.09	1.49	0.91	2.33	1.61	3.34	25.66
1907	1.05	1.68	0.73	1.24	2.07	1.77	1.85	1.23	1.37	1.55	2.60	3.60	20.74
1908	2.43	2.19	2.49	2.01	1.81	1.31	2.55	1.06	1.73	2.83	3.07	1.75	25.23
1909	2.33	2.14	3.29	3.54	2.47	2.03	1.20	3.12	1.14	2.08	2.08	4.81	29.23
1910	3.77	2.42	0.82	2.57	4.39	1.73	1.98	3.01	1.12	0.34	2.40	3.23	27.78
1911	6.64	1.57	2.35	3.31	3.96	2.43	4.29	4.08	1.35	1.57	2.83	2.48	36.96
1912	1.99	4.28	2.69	2.14	1.52	1.29	0.91	1.65	0.99	1.33	2.62	3.48	24.89
1913	1.75	1.75	4.51	2.68	2.33	2.41	1.43	2.23	0.59	1.28	2.52	2.60	26.08
1914	3.14	1.61	1.42	2.10	1.43	2.43	-	-	-	-	-	-	-
1915	2.90	1.60	1.26	3.25	4.21	1.87	2.48	3.53	1.00	0.84	2.27	2.69	27.90
1916	1.71	0.95	3.29	1.80	5.69	3.00	1.71	1.44	1.18	1.62	2.74	2.99	28.12
1917	3.87	1.39	2.10	1.52	1.39	3.25	2.09	1.[illegible]	2.50	1.15	0.98	3.22	24.68
1918	2.16	2.47	3.02	2.65	2.58	2.97	2.96	2.60	2.06	1.76	1.75	0.57	27.57
1919	1.58	2.79	1.09	3.64	5.69	2.94	2.72	2.84	2.38	1.04	1.87	2.37	30.95
1920	2.96	3.02	5.15	1.27	2.76	3.32	2.03	0.87	1.38	1.03	2.77	4.92	29.48
1929	2.87	2.80	2.76	3.15	2.01	1.93	1.37	1.99	1.43	3.01	3.09	5.84	33.84
1930	2.30	1.34	3.69	1.81	2.11	2.17	2.04	1.42	2.02	1.43	1.32	2.69	23.18
1931	2.61	2.56	3.04	3.37	1.98	2.92	1.74	1.39	0.86	1.44	2.27	2.15	27.94
1932	4.94	2.03	3.20	3.49	3.35	2.87	1.65	2.47	1.09	1.65	2.40	2.18	32.26
1933	2.03	3.03	1.80	1.50	1.02	2.00	1.38	0.87	3.41	2.76	3.59	3.26	24.13
1934	2.21	4.43	3.64	0.86	1.98	2.10	2.69	1.75	0.89	0.96	2.80	3.12	27.61
1935	2.47	4.41	1.42	5.92	3.21	2.76	2.48	2.65	1.07	0.60	2.08	3.25	33.83
1936	3.10	2.41	3.21	3.02	2.89	1.49	3.70	2.03	2.58	2.47	0.89	2.65	30.60

1937	3.46	2.92	2.32	2.45	3.34	1.36	1.46	3.28	1.01	1.44	1.97	2.76	27.77
1938	3.31	2.31	2.46	4.05	3.43	2.91	2.61	2.61	0.95	0.71	2.31	3.21	30.87
1939	3.50	1.01	2.96	4.13	3.11	1.91	1.87	1.94	1.49	1.29	4.62	3.45	31.37
1940	2.85	3.70	2.54	3.15	3.20	2.74	2.02	1.88	1.08	1.61	1.03	4.65	30.45
1941	2.91	1.33	1.86	5.87	3.2[illegible]	2.17	2.15	3.20	2.75	3.35	1.59	1.74	32.14
1942	2.60	2.17	3.13	1.69	2.20	2.40	0.85	1.89	2.85	1.06	1.46	1.38	23.68
1943	3.95	3.20	1.99	1.64	1.85	1.04	2.92	2.23	2.56	1.01	2.10	2.72	27.21
1944	2.29	2.21	1.24	1.37	2.05	2.82	4.42	2.25	0.83	2.37	1.18	4.66	28.36
1945	0.8o	2.75	2.90	3.48	2.70	3.65	2.00	2.75	3.11	0.91	0.87	3.54	29.46
1946	2.35	2.58	1.74	1.37	0.64	1.13	2.62	2.82	2.27	1.27	2.31	0.91	22.03
1947	3.56	3.16	2.86	1.66	4.07	2.08	1.36	1.00	1.10	1.19	1.57	3.32	26.93
1948	4.52	4.67	2.03	1.98	3.20	1.14	1.15	1.12	2.52	2.35	3.92	3.70	32.30
1949	1.96	2.77	4.08	1.90	1.43	3.62	0.98	2.02	1.43	0.43	1.34	3.76	25.72
1951	3.95	3.08	2.05	1.55	2.63	3.89	1.52	2.04	2.04	2.51	3.59	3.68	32.51
1952	2.22	4.55	2.98	3.18	1.38	1.18	1.99	1.49	1.44	1.10	0.99 (1st to 29th)		
Total	137.99	123.88	121.95	121.63	123.34	104.58	95.34	94.49	76.49	72.92	94.87	138.05	
No: of years observed	48	49	49	48	48	47	46	47	47	47	47	46	
Monthly Averages	2.87	2.53	2.49	2.54	2.57	2.22	2.07	2.01	1.63	1.55	2.02	3.00	27.50